Numerical Weather Prediction

Report on the diagnosis of convergence from the Nimrod wind forecast.

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Abstract

A preliminary study of the diagnosis of convergence from the Nimrod wind forecast is described and some cases studies are presented.

In the cases studied the Nimrod wind forecast generally preserved convergence lines occurring in the mesoscale model forecast and often enhanced the convergence values.

Plausible association between convective development and convergence lines was found in some cases, however weaker association or no obvious association was found in many other cases.

1 Introduction.

The purpose of this report is to describe a preliminary study of the diagnosis of convergence from the Nimrod wind forecast. In particular we seek indications that preferred regions for the initiation of convection may be inferred from the forecast convergence field, and we wish to assess whether the Nimrod forecast carries any additional value, or indeed demerit, relative to the unified model forecast for the diagnosis of convergence and any associated convection.
In section 2 the method is described and in section 3 some test cases are presented. Conclusions are drawn in section 4.

2 Calculation of convergence.

In this report the word *convergence* refers to minus the value of the horizontal divergence of the wind field. This is taken be the horizontal mass convergence; variations in density are assumed to be negligible. The horizontal convergence of moisture was also calculated in a similar manner to that shown below, but first multiplying the wind at each node by the screen total water at that node. As yet, however, no additional value has been discerned in the pattern of the moisture convergence field, so we refer exclusively to the 'dry' convergence.

Although the unified model uses a staggered grid, the fields are interpolated onto the standard Nimrod grid for use within Nimrod – thus the two horizontal components of the wind are collocated. To maximise accuracy and preserve the smallest-scale features of the convergence field, the convergence is calculated from this collocated Nimrod wind field at an offset location using differences centred on (i+0.5,j+0.5) as described in equation (1).

(1)

$$\begin{aligned} conv(i,j) = -0.5 * (& (u(i+1,j+1) - u(i\ \ ,j+1))/dx \\ & + (u(i+1,j\ \ ) - u(i\ \ ,j\ \ ))/dx \\ & + (v(i+1,j+1) - v(i+1,j\ \ ))/dy \\ & + (v(i\ \ ,j+1) - v(i\ \ ,j\ \ ))/dy\ \ ) \end{aligned}$$

where dx is the x grid spacing and dy is the y grid spacing, so that the nominal conv(i,j) is actually located at (i+0.5,j+0.5) as shown in **Figure 1**.

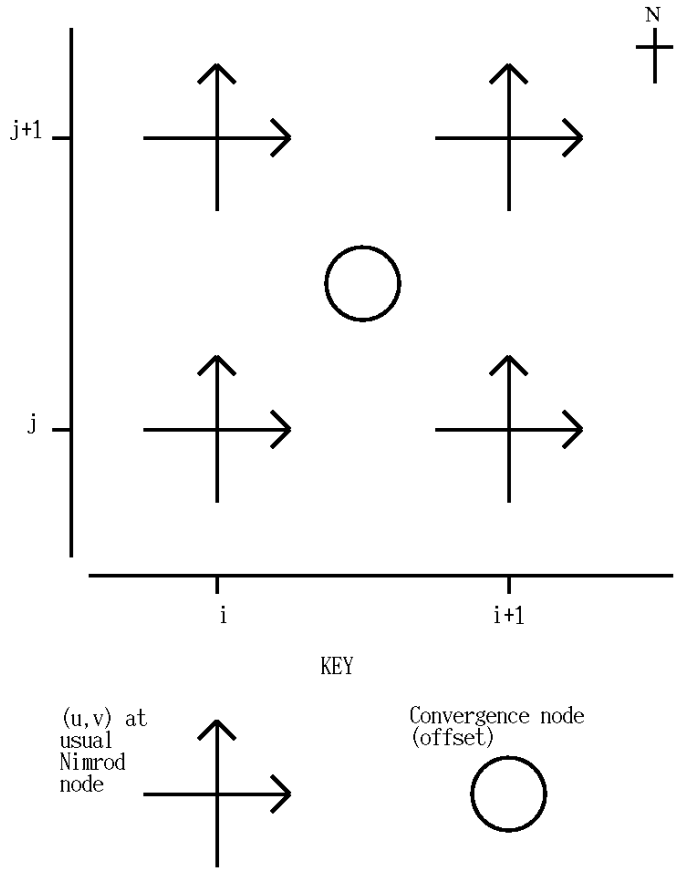

Figure 1. Schematic diagram showing collocated velocity components u and v at the usual Nimrod grid nodes and the offset location of the convergence node (i,j).

To aid interpretation of the convergence field, a visualisation of the velocity field is overlaid on the convergence images as follows. Symbols representing vectors are located on a regular but arbitrary grid and are determined by bilinear interpolation of the Nimrod wind field. Within an individual image the length of the vector symbol 'tail' depends on the magnitude of the wind, but the scaling is not preserved between images. This is to ensure each image has a reasonable length of tail without the tails overlapping.

3 Test cases.

3.1 Selection of cases

One of the most difficult aspects of the study is finding suitable cases. Sources have included NMC and the European Storm Forecast Experiment (ESTOFEX) web site. NMC produce low-level wind trajectory analyses on days when convection is likely. These show confluent areas where, if convergence is also present, convection could develop. The ESTOFEX web site has an archive of daily outlooks for severe convection over Europe. Sometimes low-level convergence is mentioned as a development mechanism. Some cases have come to light from published articles. Unfortunately, two of the most promising cases suggested by NMC – 02/06/2002 and 18/06/2002 – fall in a period for which data is not available from the Nimrod archive.

Two types of cases have been looked at, those where precipitation developed and those where sea breezes led to clear areas near the coast with cumulus cloud developing inland. It is assumed that the clear region is due to cooling by the onshore wind. It is less clear whether

the edge of the cumulus area is associated with low-level convergence. However, these cases can show how well the Nimrod wind analysis deals with the sea breeze.

As a first attempt to look at convergence within the context of the Nimrod wind forecast, some very basic issues are addressed. Because the Nimrod wind analysis and forecast are unbalanced they could produce a rougher divergence field than the mesoscale model. On the other hand they could sharpen up the divergence field. Therefore, the relative merits of the UM and Nimrod divergence fields have been considered. The study so far has concentrated on looking at a variety of cases and has not attempted an in-depth study of any case. It is apparent from the case studies that many lines of convergence are found and only a few associated with convective development. No attempt has been made to look at other factors which influenced whether convection developed.

3.2 3 July 2003: Showers in convergence zone.

The synoptic evolution guidance from the NMC for this day issued at 0400 predicts '...showers forming preferentially in convergence zones...'. The NMC guidance upon which this is based, showing a correspondence between low level convergence (or confluence) and precipitation in the UM 15-hour forecast for 1500 is shown in Figure 5 . A zone of convergence – a line extending from southern Cumbria to Suffolk – is already apparent in the midnight UM forecast (**Figure 2**) but is enhanced in the Nimrod f/c (**Figure 3**), and corresponds quite well with the Nimrod rain rate analysis shown in **Figure 4.**

Note that other strong lines of convergence are apparent in both the UM and Nimrod forecasts, particularly off the south coast of England. These are not associated with convective rain at 1300 Z.

The convergence and rainfall fields have been examined from 10 - 1400. The convergence line apparent down the centre of England in **Figure 3** appeared at 1100 but the northern branch passing through the Wash only appeared at 1300. The area of rain over SE England in Figure 4 was part of an area of rain moving eastwards. The line of convection west of the Wash reformed several times more or less in the same place, decaying as it moved very slowly eastwards This is closely associated with the convergence line, with the caveat that in the case of the Nimrod forecast, there is a gap in the convergence line where the convection forms.

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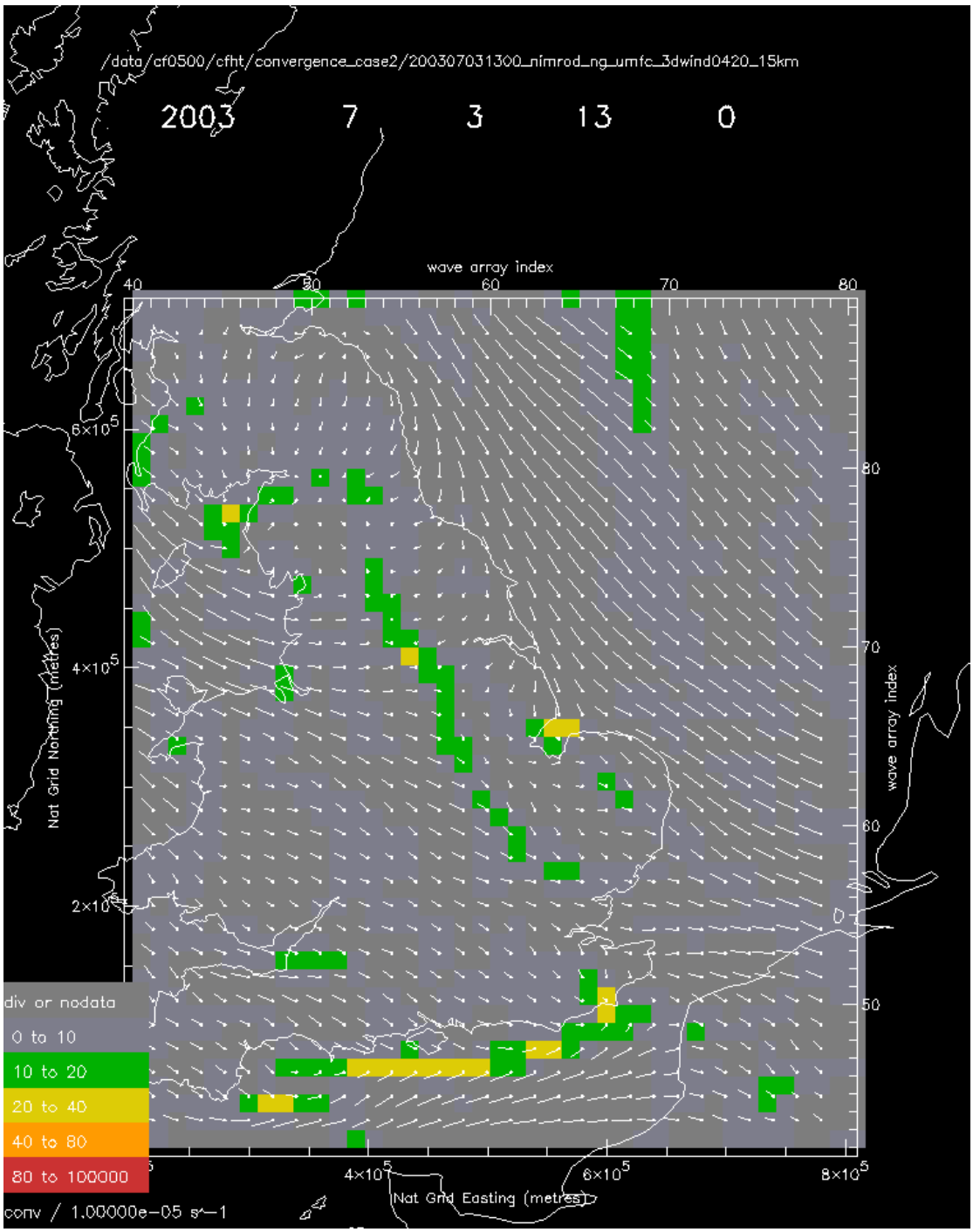

Figure 2. Convergence field derived from UM midnight f/c for 200307031300.

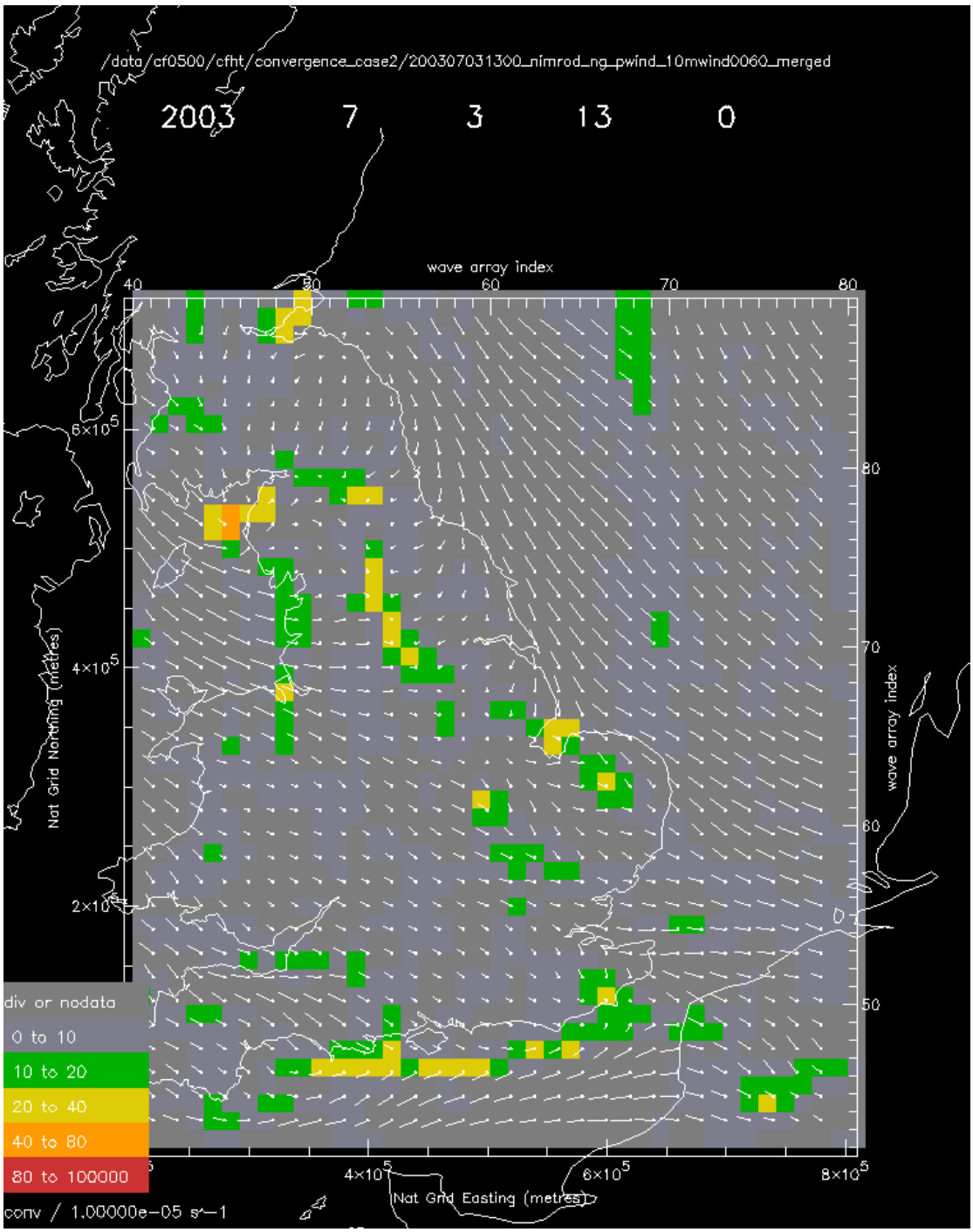

Figure 3. Convergence derived from Nimrod one-hour f/c for 200307031300.

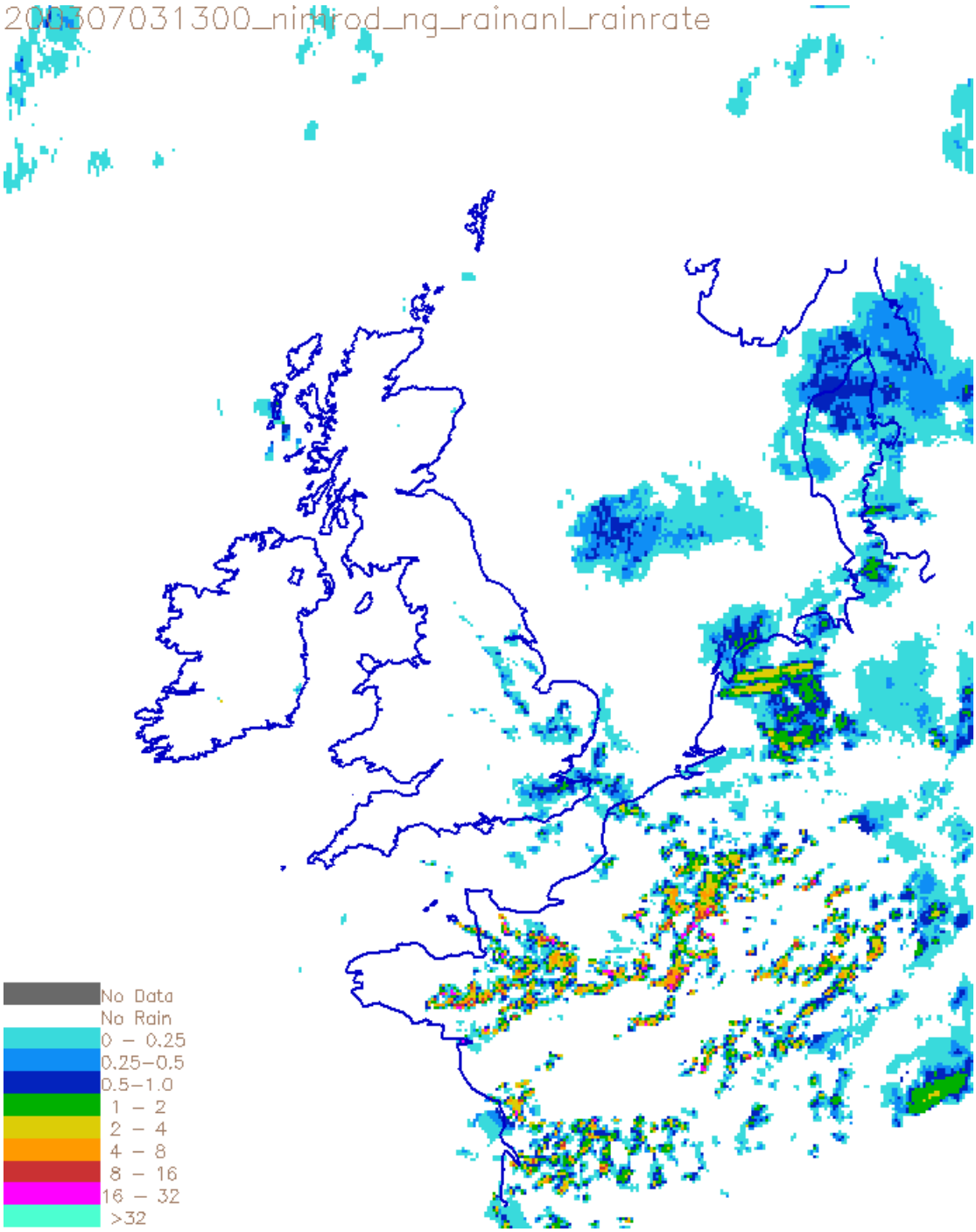

Figure 4. Nimrod rain-rate analysis for 200307031300.

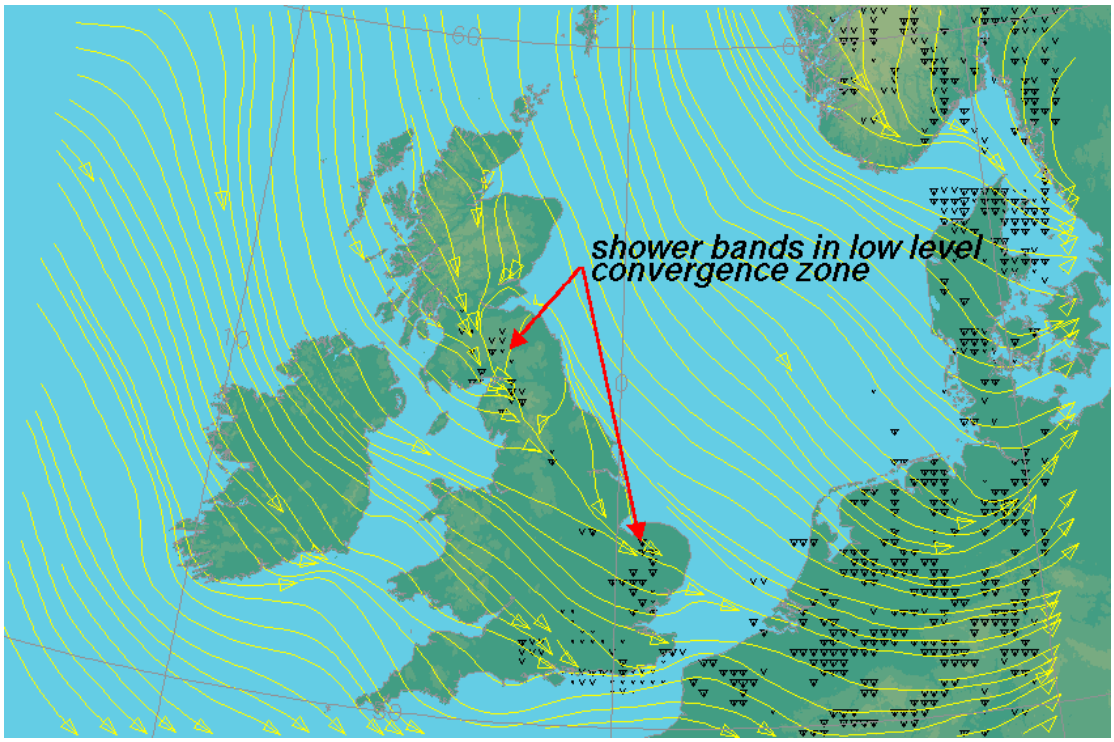

Figure 5 Mesoscale model 15-hour forecast of precipitation with low level trajectory analysis (based on midnight run model data) for 200307031500.

3.3 10 July 2003: Sea breeze on the north coast of France.

This is one of several cases looked at where sea breezes led to clear zones adjacent to the coast with cumulus cloud developing inland.

Figure 6 shows the convergence field derived from the unified model midnight forecast for 200307101400. A substantial line of convergence can be seen along the northern coast of France. This signal is enhanced in the Nimrod one-hour forecast (**Figure 7**). The convergence forecast corresponds quite well with the band of cloud over Northern France which can be seen in the satellite visible image **Figure 8**.

Both unified model and Nimrod forecasts have onshore winds along the south coast of England where a clear area is seen on the satellite visible image (**Figure 8**), but there is only a short convergence line. There is a strong convergence line oriented N-S over the East Anglian coast. **Figure 8** shows that the East Anglian coast was clear from mid-Norfolk southwards. There was a band of cloud inland from the coast but at an angle to the convergence line. Therefore, it is not at all clear that this is related to the convergence line.

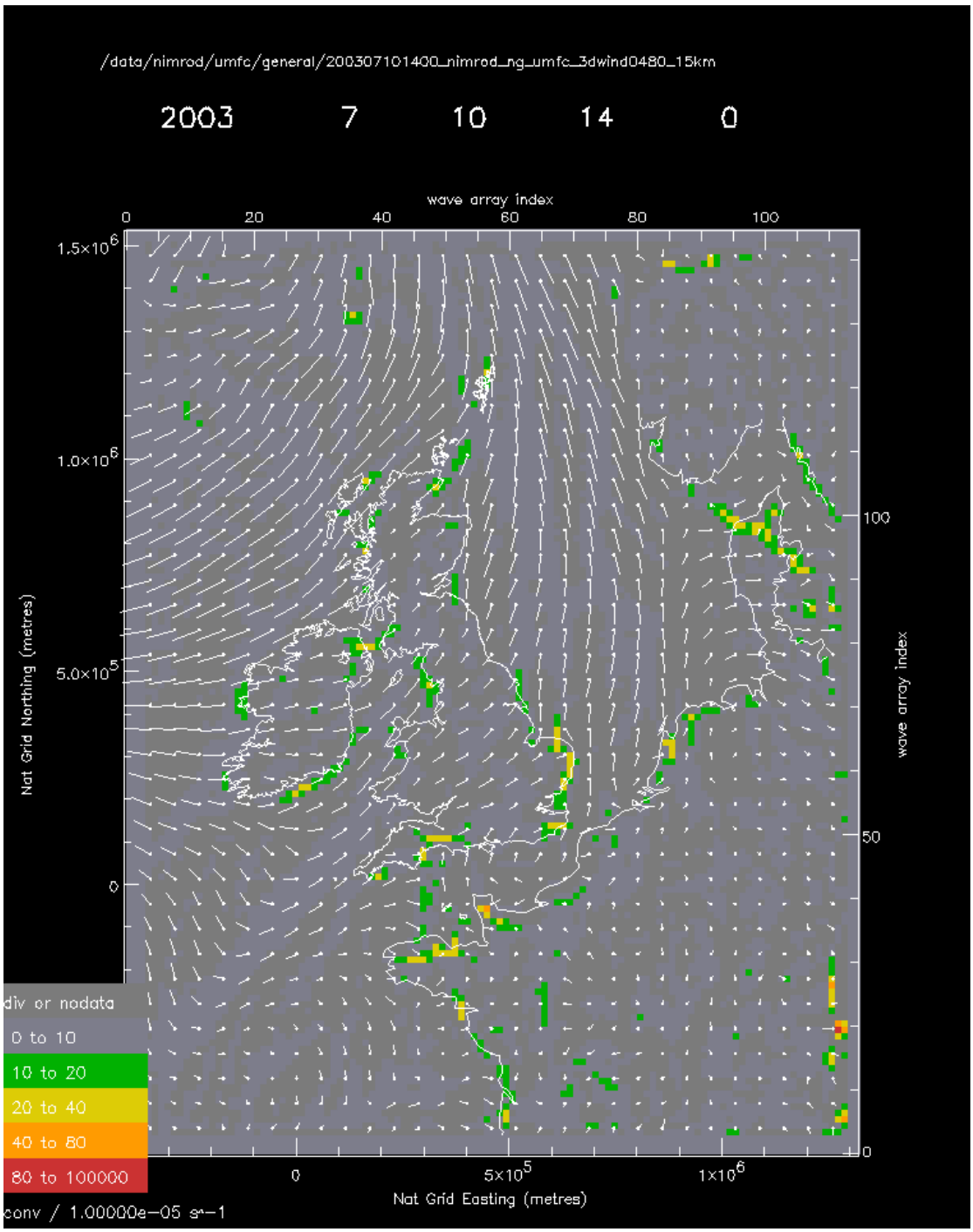

Figure 6. Convergence derived from UM midnight f/c for 200307101400.

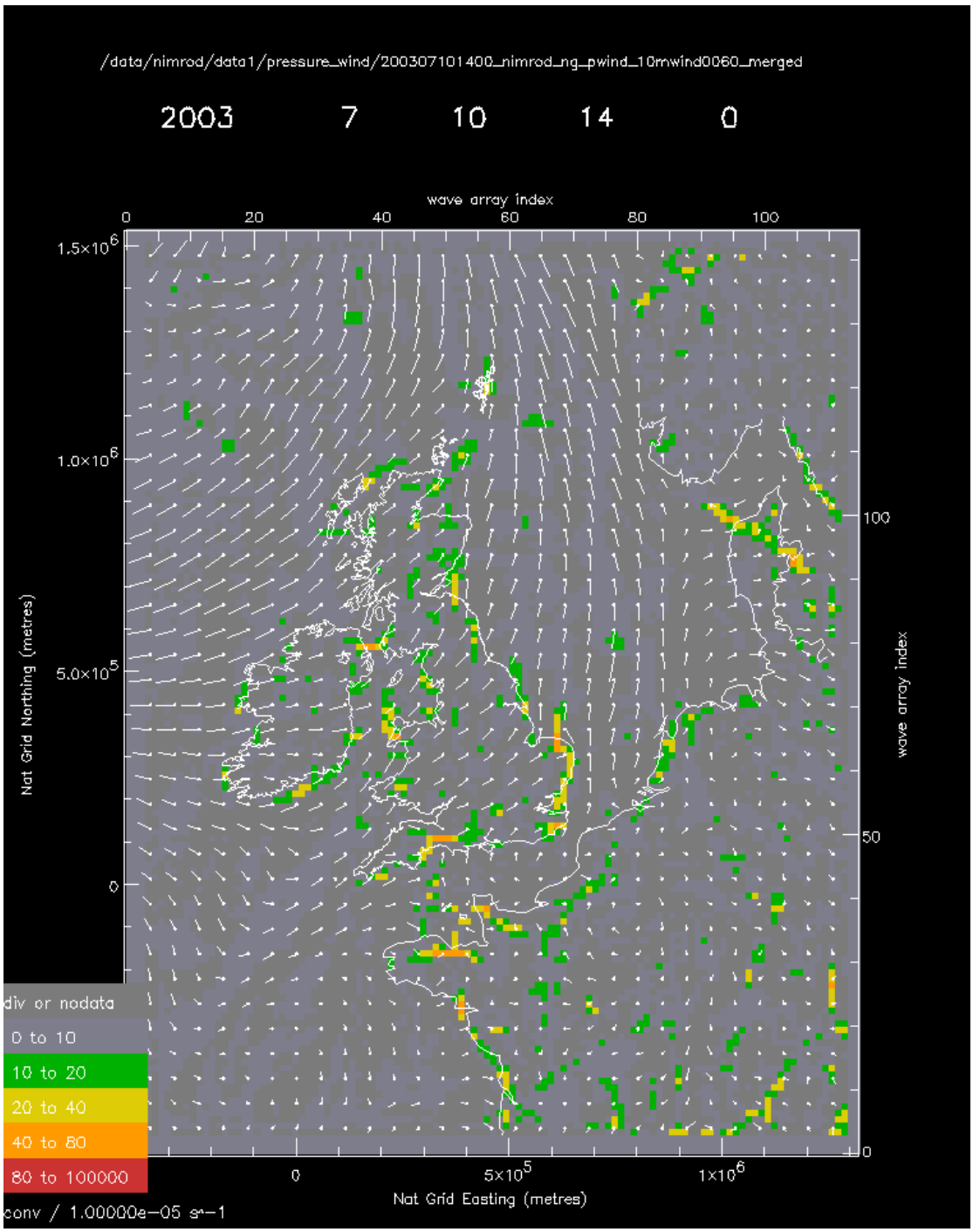

Figure 7. Convergence derived from Nimrod one hour forecast for 200307101400.

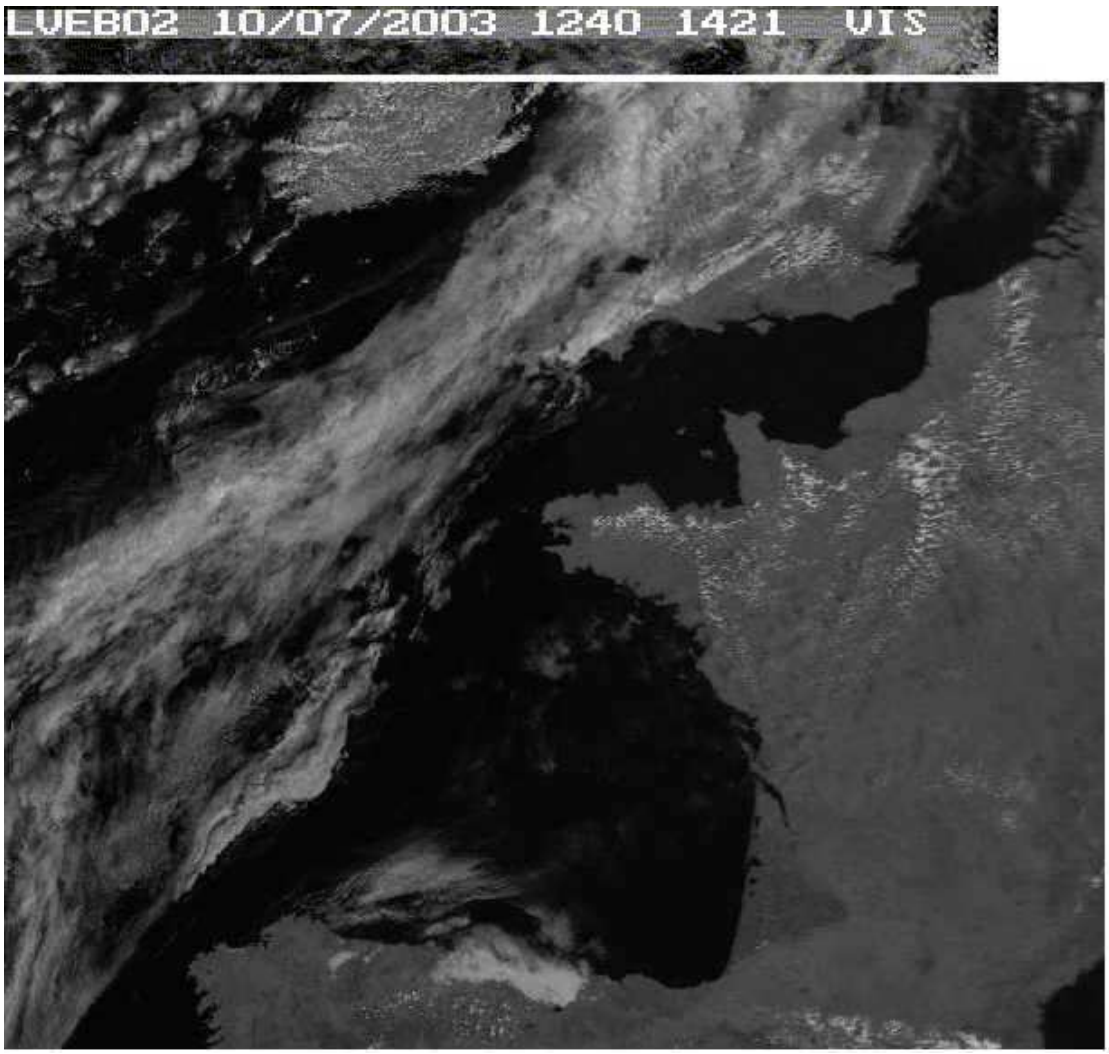

Figure 8. Detail of satellite visible image for 200307101421.

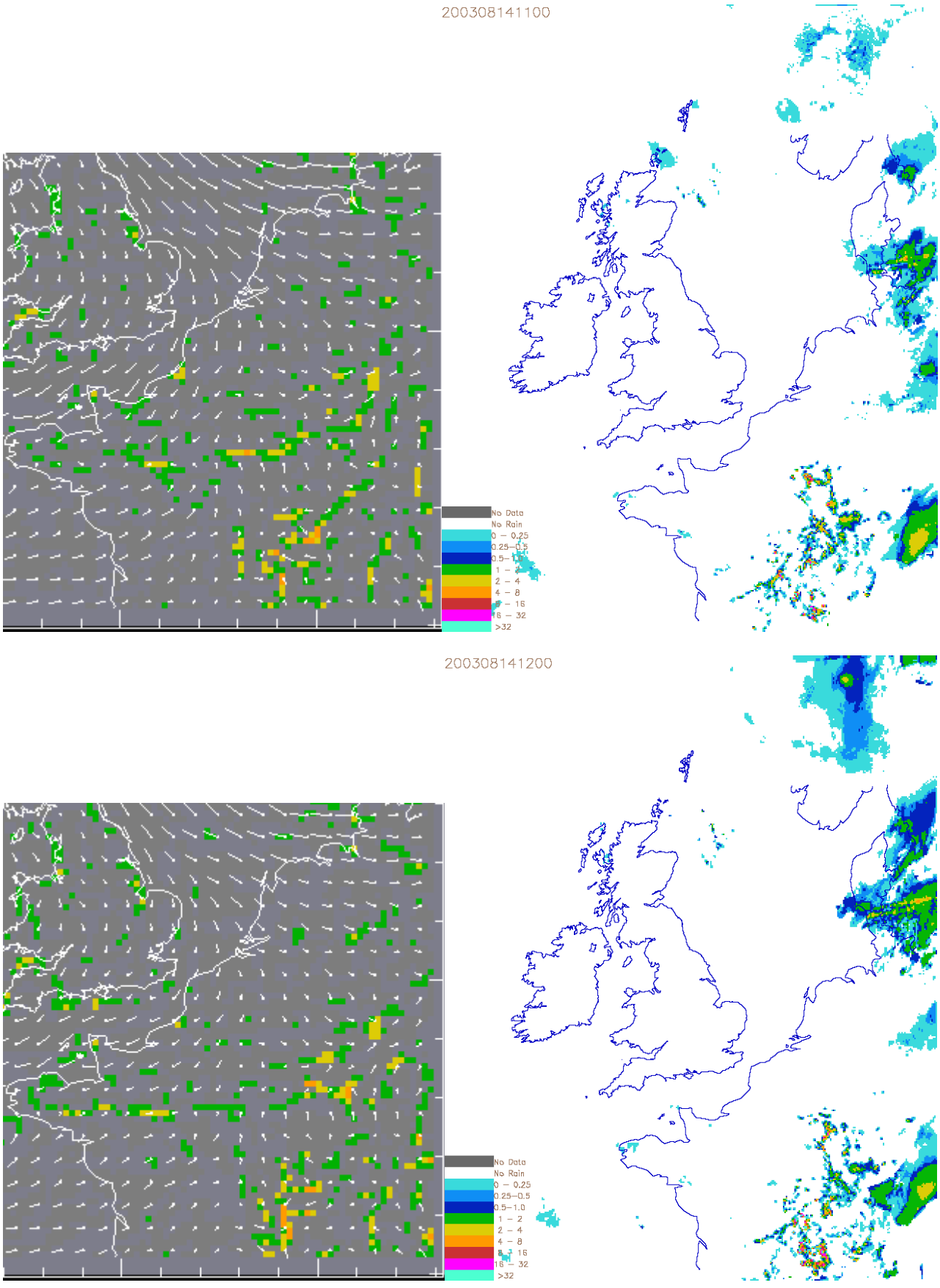

Figure 9. Convergence (left) and rainrate analyses for 1100 Z (top) and 1200 Z.

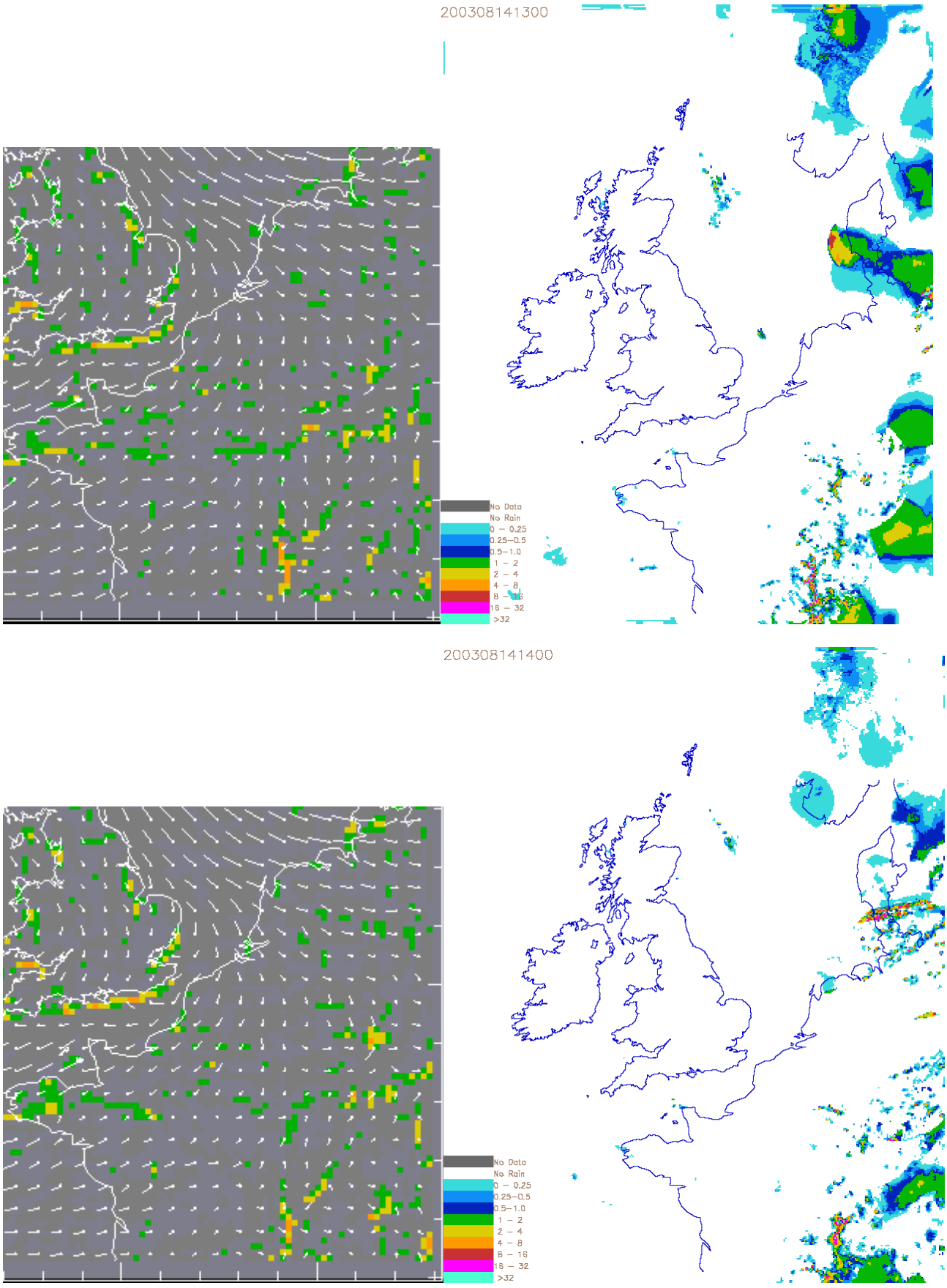

Figure 10. Convergence (left) and rainrate analyses for 1300 Z (top) and 1400 Z.

3.4 14 August 2003: Precipitation on Western flank of the Alps.

Figure 9 and Figure 10 show the development of a line of convergence to the West of the Alps. The line of heavy rain which runs approximately S-N from the bottom of the image on the right-hand side of the 1300 Z rainfall analysis may be associated with the line of convergence in the 1200 Z convergence analysis. This line is perhaps more pronounced in the 1300 Z convergence analysis, and the rainfall persists as shown in the 1400 Z analysis and at least until 1445 Z (analysis not shown). The convergence line developed between 1100 and 1200 and persisted until 1300; it is less clear by 1400. Although convection existed at 1100, it was rather disorganised. However, by 1300 the dominant convective feature was associated with the convergence line. Also, the convergence preceded the development of this convective line.
Again there are other convergence lines not associated with convective development.

Satellite images for 1100, 1200 and 1400 Z are shown below.

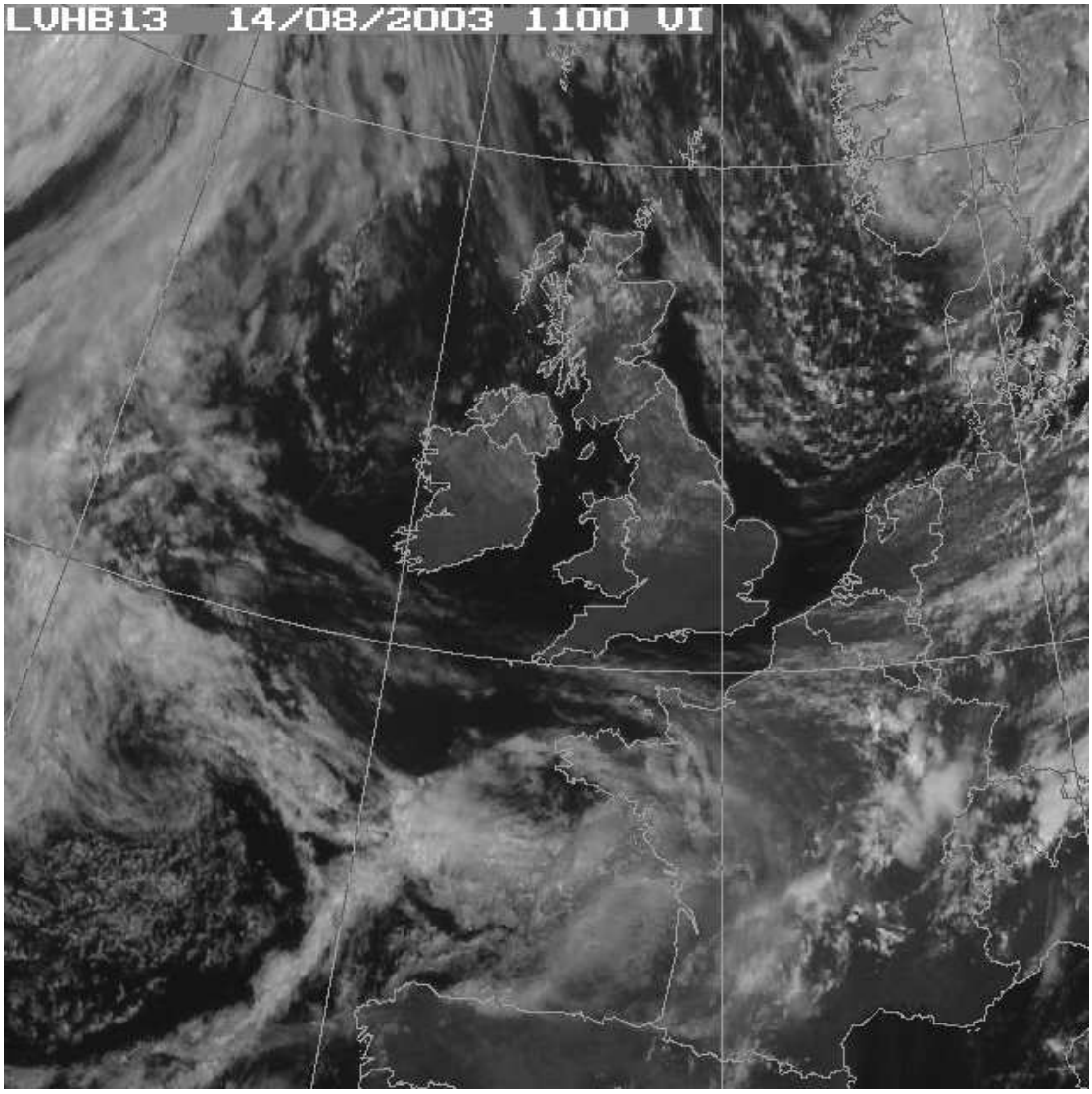

Figure 11

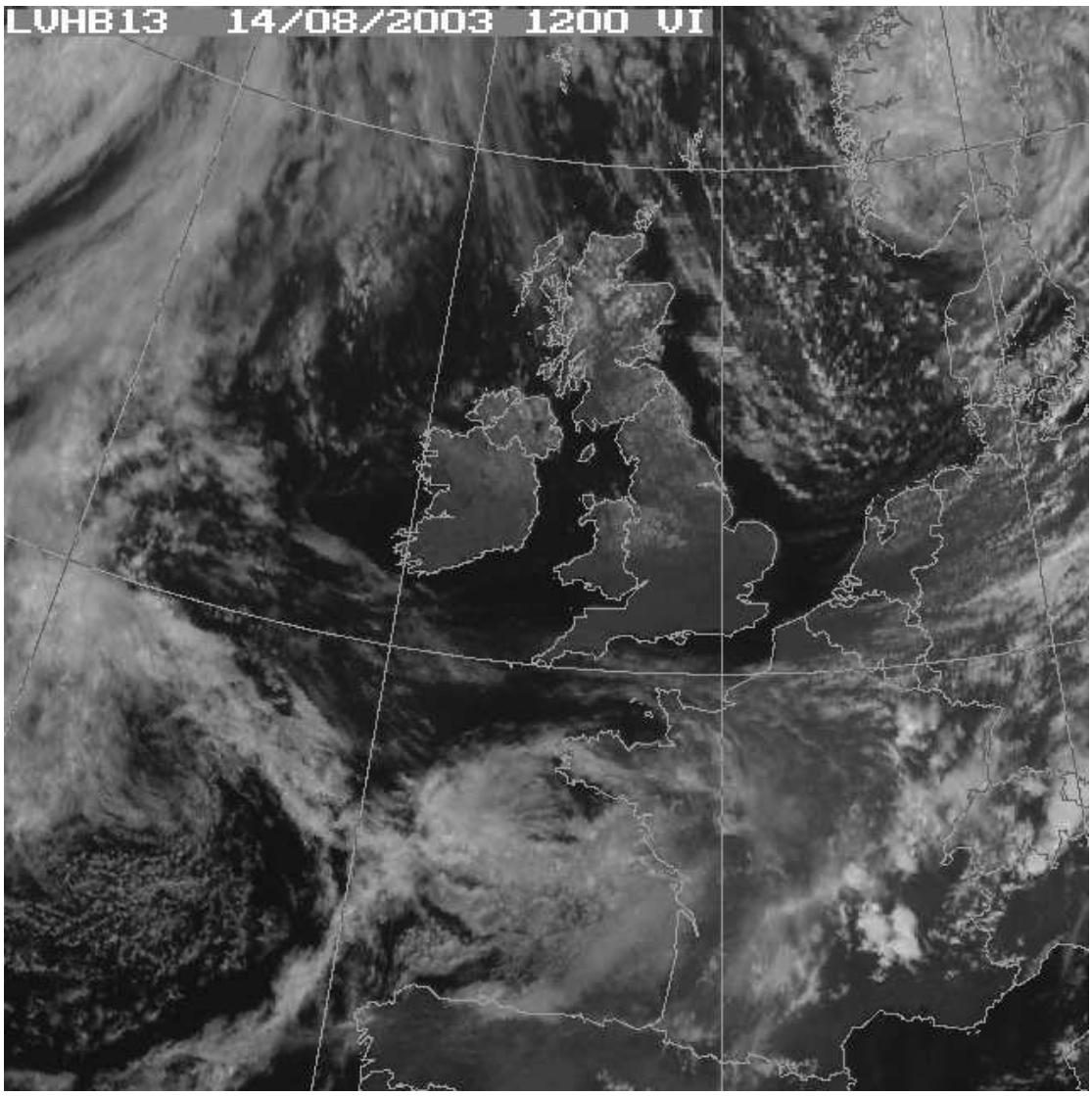

Figure 12

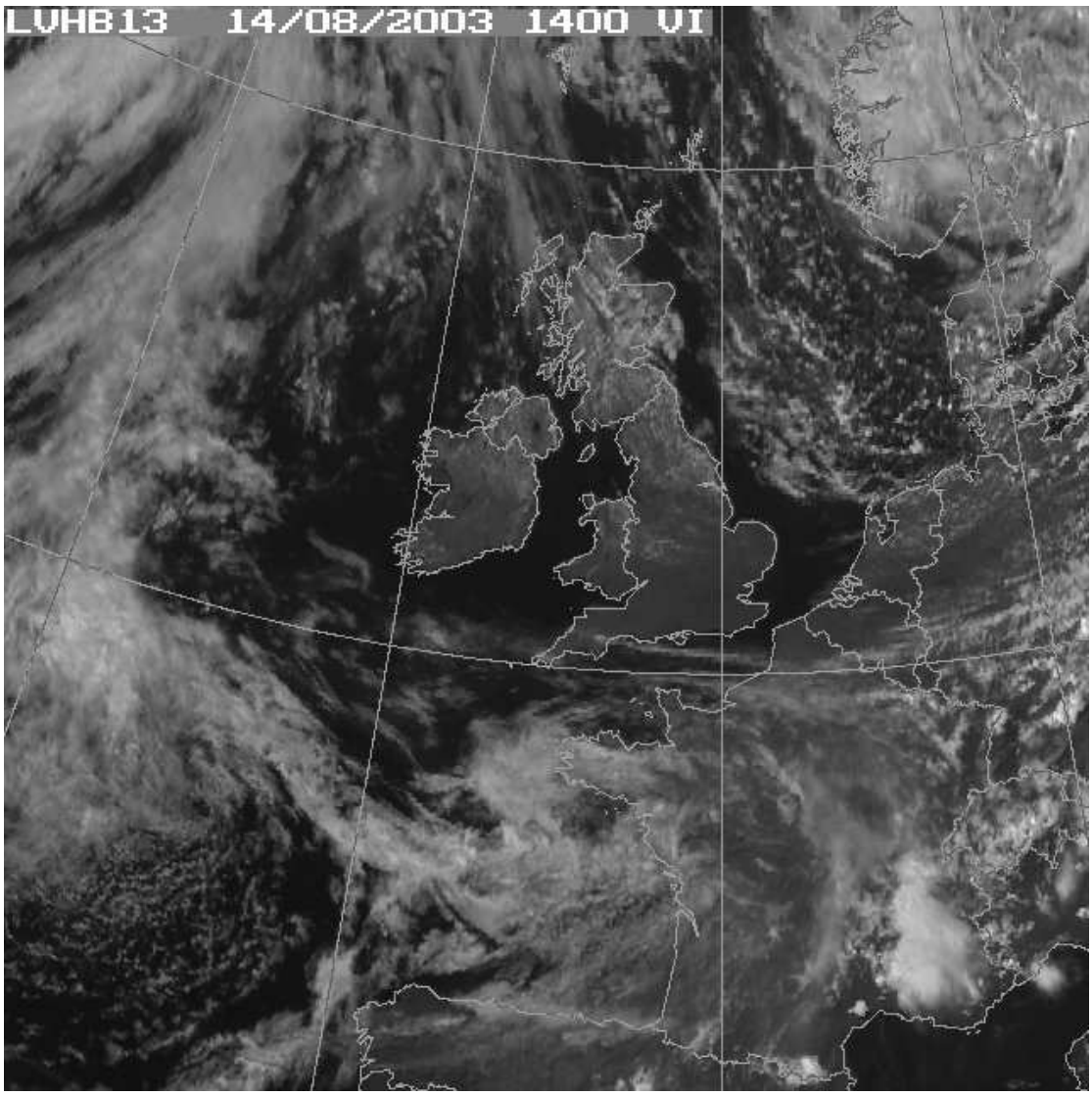

Figure 13

3.5 16 June 2003: Development of convection over northern France.

On this occasion forecasters in the National Met Centre identified lines of confluence based on the Horace trajectory analysis. Correspondence between this and the polar orbiting satellite visible image taken 30 minutes later is shown in Figure 14. The NMC analysis has several confluence lines. The two major storms over France appear to be developing towards the southern edge of the visible cloud shield with upper outflow towards the NNE. The southern end of the most northern storm is situated close to the southern end of the N-S confluence line. The southern edge of the other storm is associated with the E – W confluence line at the southern boundary of Figure 14.

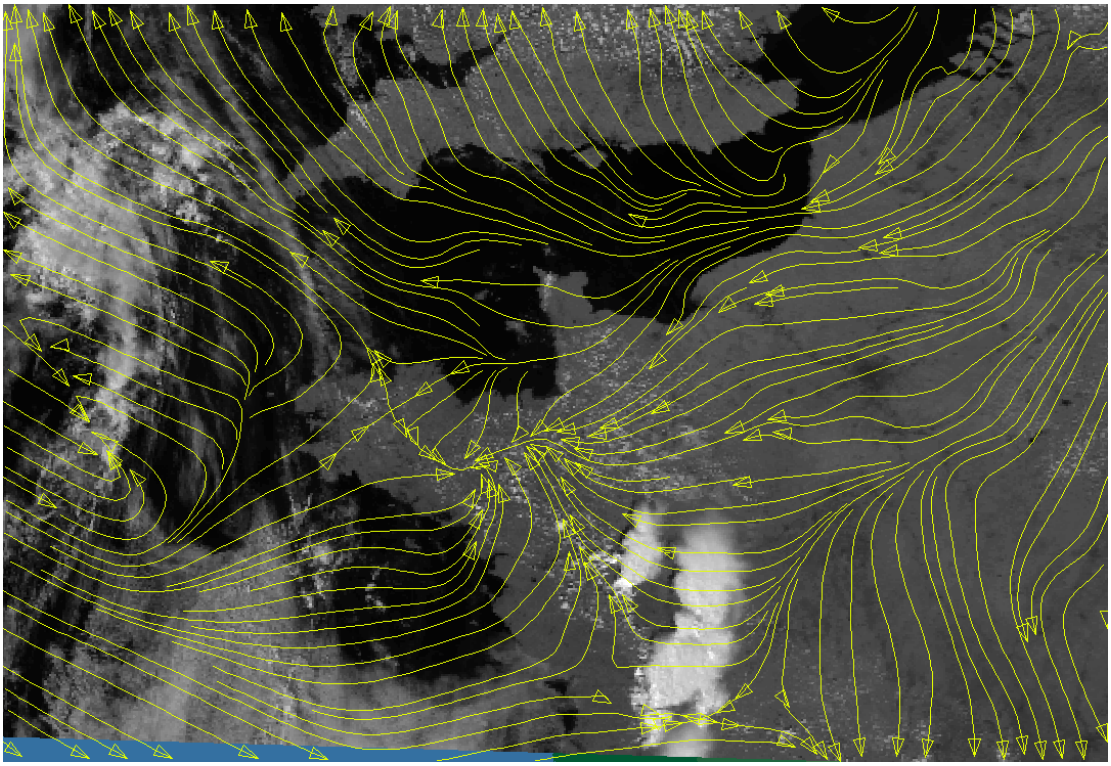

Figure 14 1330z polar orbiting satellite visible image and 13z Horace confluence analysis from the observations (20030616).

Convergence fields for the six-hour UM forecast and the one-hour Nimrod forecast are shown in Figure 15 and Figure 16. Some of the convergence features in the UM field are enhanced in the Nimrod analysis, especially the line over the SW peninsula, where there was no confluence. However, these were not associated with convective development. The confluence lines closest to the storms are associated with small areas of convergence in the model wind field. There is a small convergence feature, slightly enhanced in the Nimrod wind field, close to the northern storm but this is not a significant feature relative to many of the other convergence features in Figure 16. There is a small intense convergence feature just inland of the French coast at the southern boundary of Figure 16 but this is farther east than the southern storm.

All one can conclude from this case is that the Nimrod wind analysis contains enhanced convergence features relative to the UM but the two major storms over France seem better associated with the confluence lines in the NMC analysis. There is no obvious physical explanation for this.

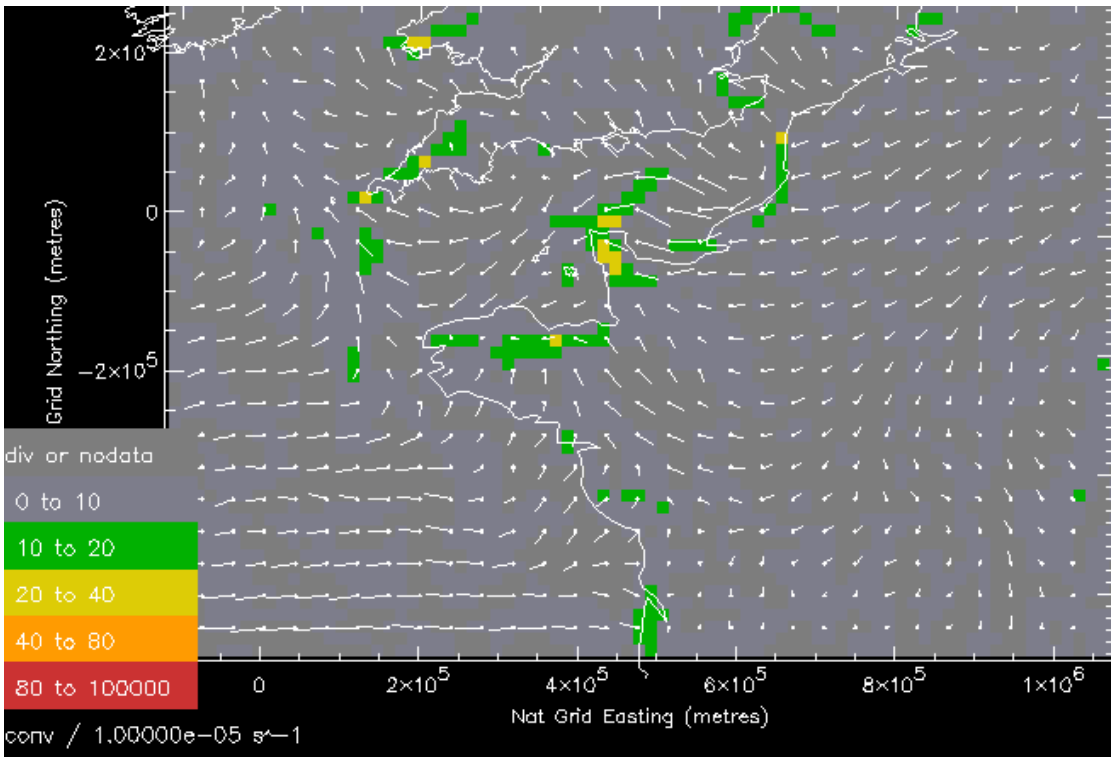

Figure 15. Convergence field of 6 hour UM forecast for 1200

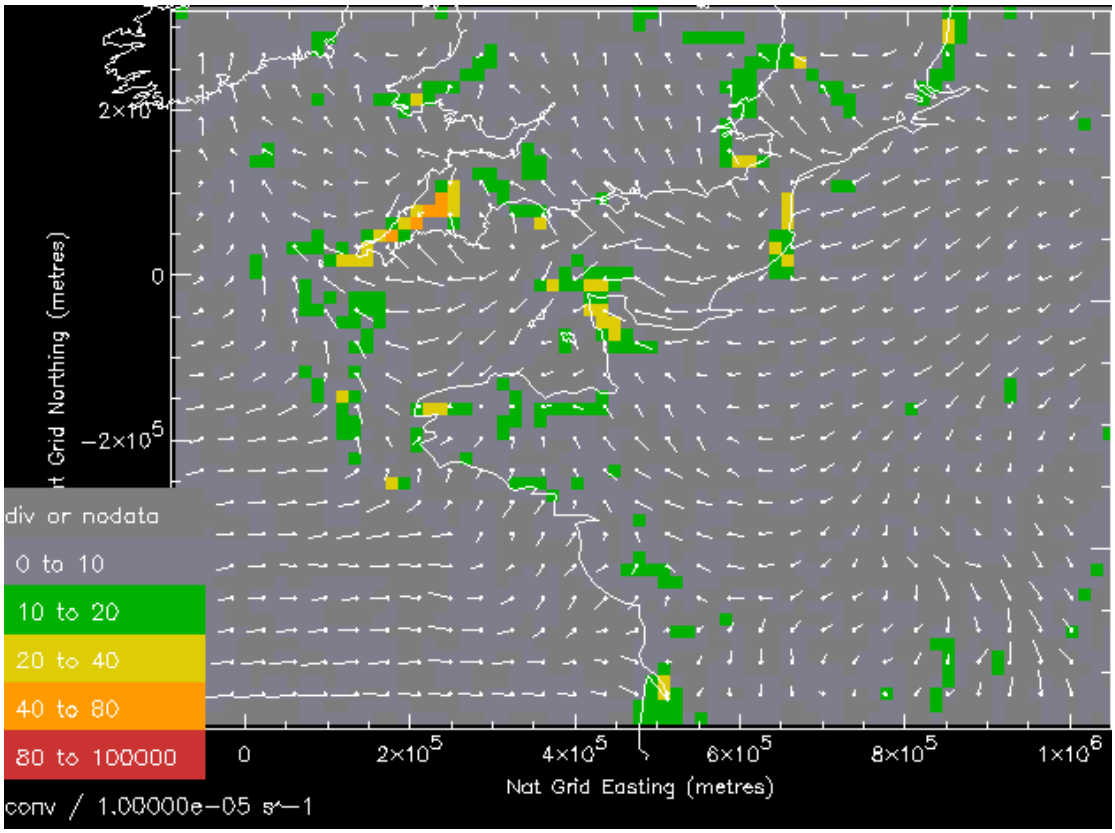

Figure 16 Convergence field of Nimrod one hour forecast for 1200.

4 Conclusions

In the cases studied the Nimrod wind forecast generally preserved convergence lines occurring in the mesoscale model forecast and often enhanced the convergence values. Occasionally it made a convergence line more broken e.g. **Figure 2** and **Figure 3**. There was approximate agreement between the confluence lines diagnosed by NMC and the convergence lines diagnosed from the mesoscale model and Nimrod wind fields, although there were differences in detail.

Plausible association between convective development and convergence lines was found in each case shown here. Weaker association or no obvious association was found in many other cases (see appendix). Temporal evolution was considered in reaching this conclusion, to try and ensure that the convective feature being associated with a convergence line had not advected from elsewhere.

In each case, several convergence lines existed at locations where no convection developed. These often had higher convergence values than those associated with convection This is hardly a surprise and any practical application of this study would be in a system such as GANDOLF, where the other elements required to initiate convection would also be considered. Lines of high convergence values just offshore and following the coastline were a regular occurrence but were not associated with convection in the cases studied here.

Concerning future work, it has to be decided whether it is worth performing a more detailed meteorological analysis of the test cases, to try and confirm that conditions were not generally suitable for convective development where there was marked convergence but no convection.

5 Appendix: Other Cases Examined

19 July 2000
Another sea breeze case over Northern France with a clear slot, then cumulus developing inland. Nimrod has onshore winds over the north coast of France but no convergence inland. Strong convergence lines are found around many other coasts, mainly just offshore.

16 July 2001
There were Cb over East Anglia at 1800 but not associated with convergence. A line of showers over Northern France could be associated with a line of convergence.

29 May 2003
Another case with a clear slot over Northern France and cumulus inland of this. The edge of the cumulus field is quite well related to a convergence line. The convergence lines in Nimrod are noticeably more pronounced than in the mesoscale model. A line of convective cloud running NNE from the southern Pennines is associated with a convergence line at a slightly different orientation. However, the convection could be triggered by the Pennines.

17 June 2003
At 1200 there was a strong convergence line over East Anglia, together with a large area of thunderstorms. However, the convection initially developed as a line over SE England, without an associated convergence line and then moved NNE into East Anglia where it developed into a large area. During the initial development over East Anglia the convergence line was just north of the convective area but they became more coincident later. The

question is did the convergence promote the development or did the convective area produce the low-level convergence.